An Empirical Study Into the Limitations and Emerging Trends of Six Sigma

An Empirical Study into the Limitations and Emerging Trends of Six Sigma: Findings from a Global Survey

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Abstract

The purpose of this study is to identify and evaluate the limitations and emerging trends of Six Sigma from the perspectives of Six Sigma experts. The authors developed an online global survey and deployed the survey to 1250 Six Sigma experts of which 307 experts responded. The study finds *integration of Six Sigma with Big Data* to be the topmost among Asian, South American, and African experts, whereas as European and North American experts felt *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises would be very beneficial*. The manufacturing sector experts nominated the topmost emerging trend as Six *Sigma in Small and Medium Sized Enterprises and Micro-enterprise*s to be very challenging and will be rewarding if implemented properly. In the service sector the topmost emerging trend, was the integration *of Six Sigma with Big Data*. However, public sector experts felt *variance reduction should not be the only goal of Six Sigma implementation*. The study further finds that master black belts perceived *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises would be advantageous*, whereas Black and Green Belts perceived *Integration of Six Sigma with Big Data to be topmost emerging trend*.

Keywords: Six Sigma, Limitations, Emerging trends, Empirical Study

1. Introduction

Six Sigma is employed by many organizations as a business strategy for the purpose of business process improvement since its origins in the mid-1980s [1]–[3]. Six Sigma implementation has led organizations to save millions of dollars as a result of its implementation. Prominent organizations including; Allied Signal (also known as HoneyWell), General Electric, Caterpillar, Cummins, ABB, Johnson and Johnson, American Express, and Bank of America attribute bottom-line savings to Six Sigma initiatives [4]–[6]. One of the most comprehensive definitions of Six Sigma, taking into account both the "what" and the "how" of the theory, was proposed by Schroeder et al. [7], who defined Six Sigma as "*an organized, parallel-meso structure to reduce variation in organizational processes by using improvement specialists, a structured method, and performance metrics with the aim of achieving strategic objectives*". Six Sigma is also understood as a change management philosophy which can trigger a positive effect within organizations [7]–[9].

The majority of studies primarily agree on the positive effects of Six Sigma such as cost savings and defect reduction [10]–[14]. However, at the same time, it is estimated that 62% of Six Sigma initiatives have failed [15]. There are several examples of failures implementing Six Sigma [16], [17]. Six Sigma like any other quality improvement initiatives starts off well, but, as time progresses, it may fail to have a lasting impact. As a result, the motivation drops and organizations fall back into the same old habits [18]. A national survey, in the healthcare companies indicates that 54% of the companies do not really intend to implement Six Sigma [19]. Additionally, there are studies which advocate that intensive efficiency orientation will eventually damage long term variables such as organizational growth [20], [21].The limitations of Six Sigma from previous studies are elucidated in table 1. In order to address these limitations of Six Sigma, it is necessary to identify the Six Sigma limitations from the Six Sigma expert's perspectives.

Furthermore, the modern organizations are changing due to the fourth industrial revolution. The big data generated from modern manufacturing process have to be used in a proper manner for a meaningful analysis [4]. Besides, environmental aspects should also be considered in Six Sigma [22]. In addition, the success of Six Sigma in SME and micro enterprises is also a challenge[23]. As Six Sigma has been evolving over the past 30 years, the authors felt that it is important to understand the emerging trends of this powerful business strategy and the future directions so that academics can address them by working closely with professionals in industry. The emerging trends of Six Sigma from previous studies are elucidated in table 1.Therefore, an empirical evaluation of these emerging trends of Six Sigma from Six Sigma expert's perspectives would help to understand the areas to be focused on for future research Previous studies have described Six Sigma criticisms [2]. This study contributes to this research, running an empirical investigation that evaluates the limitations and emerging trends through Six Sigma experts' knowledge from around the world. Six Sigma implementation differs in manufacturing, services and public services [2], therefore it would be interesting to analyse the limitations and emerging trends from the perspectives of Six Sigma experts working in these areas. Further, Six Sigma is well implemented in continents such as North America and Europe however, its implementation in Africa has been scanty[24]. Therefore, the analysis of limitations and trends from Six Sigma experts across the continents will add diverse viewpoints. Lastly, knowledge and responsibility of Six Sigma experts differs according to different Six Sigma belts [25] and also to the years of Six Sigma experience[24] and therefore, the limitations and emerging trends needs to be explored from the perspective of different Six Sigma experts. In a nutshell, the purpose of this study is (a) to identify the top five limitations and emerging trends of Six Sigma from the viewpoint of Six Sigma experts from different continents, belt wise, years of experience and sectors (manufacturing, service & public sector);

The rationale for treating the same together is because limitations depict inherent challenges within the Six Sigma methodology and emerging trends depict the future roadmap of Six Sigma. Combined analysis will depict significance of position of limitations with respect emerging trends so that practitioners and researchers can use the relative understanding to expand the Six Sigma methodology.

(b) to test Six Sigma experts' perceptual differences in limitations and emerging trends of Six Sigma as according to belt wise and years of experience in Six Sigma

This is the first paper to empirically evaluate the limitations and emerging trends of Six Sigma through a global survey of Six Sigma experts, including different contextual aspects in the analyses. There is a lack of studies of this magnitude, which offer a more complete diagnosis of the reality of Six Sigma implementation. This study will help the practitioners to understand and develop solutions to overcome the limitations of Six Sigma implementation and future challenges within the organizations. A detailed literature review relating to the top ten limitations of Six Sigma and the five emerging trends of Six Sigma is presented in Section 2. Section 3 describes the research methodology employed in this study. Section 4 presents an in-depth analysis of the data and a discussion on the major research findings and Section 5 outlines the conclusions of this study.

2. Literature Review

Through a systematic literature review, Sony et al. [2] identified the limitations of Six sigma and emerging Six sigma trends which are discussed below.

2.1 Ten Limitations of Six Sigma

The first limitation of Six Sigma is identified as high failure rate. Glasgow et al. [26] and Albliwi et al. [15] reported that over 60% of Six Sigma initiatives in organizations failed to deliver the desired results. Interestingly, the benefits resulted in the first two to three years

but the desired results were not realised. One of the main reasons attributed to Six Sigma failure was a drop in enthusiasm, resulting in many organizations reverting to former work practices [18]. Studies indicate that approximately 60% of all corporate Six Sigma initiatives fail [16], [17], [27], [28]. As a result, Six Sigma initiative failures cost many organizations a considerable amount of money. It may be challenging to identify where failures occurred as the levels at which failures can occur may vary including individual, team, project or organizational. Such factors for high failure rate should be studied in greater detail in order to understand the failure mechanism.

The second limitation concerns the high cost of Six Sigma implementation, especially during early implementation stages [29]. When implementing process improvement strategies, high start-up costs can often act as an unfavourable factor for organizations [30].

The third limitation associated with Six Sigma is identified as a negative impact on customer satisfaction if Six Sigma is not implemented properly [31]–[33]. Two major US corporations have abandoned their Six Sigma initiatives due to their negative impact on customer satisfaction [27], [31], [32]. However, studies also suggest that Six Sigma promotes customer satisfaction and innovation [34]–[38].

The fourth limitation identified suggests that inadequate Six Sigma implementation leads to a negative impact on employee satisfaction. One study has shown that varying levels of Six Sigma implementation results in differing levels of job satisfaction [39]. Another study also suggests that poor Six Sigma implementation can have an negative impact on employee morale and engagement [40], because of the structured methodology in its implementation.

The fifth limitation of Six Sigma indicates that the structured and disciplined nature of this type of problem-solving approach can stifle employee creativity and innovation [31], [32]. Six Sigma’s structured sequence of steps and rigorous analytical method can also lead employees towards rigidity [17], [33]. This argument has led to two interesting viewpoints.

The first viewpoint suggests that Six Sigma stifles employee's innovation skills [17], [31], [32] and the second viewpoint suggests that Six Sigma fosters innovation [41], [42].

The sixth limitation of Six Sigma suggests that any benefits accruing from Six Sigma are low in relation to both the effort and the cost invested [43]. Studies contend that lower benefits accrue from Six Sigma initiatives, in comparison with the amount of effort invested (in terms of resources and time) [27], [43], [44]. However, studies also suggest that Six Sigma implementation has resulted in significant financial savings [25], [45], [46]. Furthermore, very few Small and Medium sized Enterprises (SMEs) have reported that the ratio of investment to benefits resulting from their Six Sigma initiatives is low.

The seventh limitation revolves around the fundamental assumption of a 1.5 σ shift in the process mean for any long-term variability study in business processes. Ramberg (2000) suggests that such an assumption is groundless, and makes little sense from a practical perspective. Without σ shift, the process would have produced defects at a rate of two parts per billion [47], [48]. When the process mean shifts by 1.5 σ, the defect rate will increase from 2 parts per billion to 3.4 defects per million opportunities [49]. However, these assumptions do not hold true for non-manufacturing processes including; billing, recruitment, admissions, customer complaints handling and surgical processes in hospitals etc. [1], [50], [51].

The eighth limitation is devoted to the over-importance that Six Sigma places on variance reduction in processes. Although Six Sigma is a powerful methodology for understanding and reducing process variation, it is equally important to also consider the trade-off between the degree of variability reduction and potential accruing benefits [3], [50]. This fundamental concept is used by organizations to build a culture within the organization [52]. However, variation reduction is only one aspect of organisational inefficiency to be considered and should not always be the only focus.

The ninth limitation of Six Sigma concerns an understanding regarding what is novel in Six Sigma. Many researchers have depicted the fundamental differences of Six Sigma with many quality improvement initiatives of the past including Total Quality Management and Lean [5], [6], [25], [53]. Snee (2004) provides a detailed commentary on the critical differences between Six Sigma and TQM. Six Sigma places an unprecedented emphasis on the financial savings to be generated and on the commitment of senior executives in organisations. The second distinguishing aspect is that a clear and specific infrastructure is required for the successful deployment of Six Sigma. The infrastructure includes champions at various levels of Master Black Belt, Black Belt, Green Belt and Yellow Belt. Lastly, Six Sigma is not just focused on the use of specific tools but rather on the integration of such tools in each phase of the problem-solving methodology.

The tenth limitation of Six Sigma is an overarching criticism regarding the non-standardisation of the education/training curriculum and associated delivery method. Lauraeni and Antony (2011) suggest that there are issues with curriculum non-standardization and associated training delivery. Many trainers provide off-the-shelf training materials to service and other non-manufacturing sectors. Furthermore, scant attention is paid to the customisation of Six Sigma curriculum for SMEs and public sector organisations. A non-standardised education system also facilitates the development of a variety of learning patterns and behaviours, which may be unfavourable to the successful implementation of Six Sigma and also to its future growth.

2.2 Emerging trends in Six Sigma research

The first emerging trend associated with Six Sigma is its integration with Big Data [4]. Few studies have explored the relationship between Six Sigma and Big Data. However, Big Data was used for identifying real-time defects and their root causes in processes[54]. They

further propose "*a novel approach for data-driven Quality Management in industry processes that enables a multidimensional analysis of the anomalies that can appear and their real-time detection in the running system*".

The second emerging trend and gap in Six Sigma research is the integration of Six Sigma with Green initiatives. Green Six Sigma is associated with the assessment and reduction of the direct and ultimate environmental impact of all processes and products of an organization [22]. The integration of Green and Six Sigma concepts would create efficiencies and provide further opportunities to improve and sustain organisations' environmental footprints. Moreover, the authors further argue that such an integrated approach could provide benefits such as; reduced cost, decreased consumption of raw materials, decreased wastewater, longer resource life (through reduced usage, reduced emissions, reduced energy consumption), and improved employee health and safety (due to less exposure to harmful chemicals).

The third trend of Six Sigma concerns the challenge of its integration with Industry 4.0 [55]. Industry 4.0 is a concept better known as the "Smart Factory" where machines are connected together as a collaborative community, in order to collect, exchange and analyse data systematically in a self-regulated manner [56], [57]. Six Sigma integration with Industry 4.0 has the potential to make a highly optimized ideal process flow defect-free with minimum wastage [58]. In the health service sector, the integration of Six Sigma with Industry 4.0 has resulted in improved quality of patient care as well as reduced operational costs [59].

The fourth emerging trend of Six Sigma is its applicability in SMEs, particularly in small and micro enterprises with less than 10 employees [23]. Within SMEs generally, there remains issues regarding the availability of talented staff in executing projects along with a consideration of budget and time constraints. The current literature gaps on Six Sigma's applicability in SMEs includes questions such as: How many Green Belts and Yellow Belts are required for the successful deployment of LSS in an SME environment? What is the

scope of Six Sigma projects in an SME environment? and what is the nature of Six Sigma curriculum most suited to SMEs? [60].

The fifth emerging trend of Six Sigma is its suitability as an initiative in public sector organisations. Many studies are published on Lean and its applications in various public sector contexts such as healthcare and education [61]. However, studies which explore the impact of Six Sigma on local councils, higher education institutions, emergency services, municipalities etc. should be further researched for its long-term suitability[37], [62].

Table 1: Summary of Limitations and Emerging trends

Sr. No	**Limitations of Six Sigma**
1	The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high
2	The initial cost of implementing Six Sigma in an organization is very high
3	Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction
4	Poor implementation of Six Sigma can have a negative impact on employee satisfaction.
5	Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation
6	The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts
7	The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instil confidence in Organizations to implement Six Sigma
8	Variance reduction should not be the only goal of Six Sigma implementation
9	Six Sigma is TQM on steroids
10	Non-Standardization of Curriculum
	Emerging trends of Six Sigma
1	Integration of Six Sigma with Big Data can bring superior results to many organizations in the future
2	Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies
3	Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics

Table 1: Summary of Limitations and Emerging trends

Sr. No	Limitations of Six Sigma
4	Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly
5	Six Sigma is not suitable for public sector organizations

2.3 Contextual factors

Six Sigma challenges in non-manufacturing sector are varied in nature. Some of the challenges in non-manufacturing sector are service (non-production) focused environments struggle with metrics identification, creating a measurement of a process, dealing with customer variability, face difficulties with creating cultural change and creating Six Sigma leaders and failure to capture the benefits of Six Sigma application [63]. In public sectors the drive to look at public bodies and services has not only been caused by financial drivers, but factors such as equality of access to services, tackling unfairness and inefficiencies have also been factors to consider, therefore challenges of implementing Six Sigma is varied [62]. Therefore, it is pertinent to examine the differences of the limitations and emerging trends of Six Sigma in terms of manufacturing, services and public sectors for any differences.

Further, the national culture influences the effective implementation of Six Sigma [40]. The rapid growth of Six Sigma in US corporations compared to those in Europe is due to a better cultural fit, whereby US corporations are typically decentralized and formal [64], [65]. In addition, Six Sigma is well implemented in continents such as North America and Europe however, its implementation in Africa has been scanty[24]. Therefore, the limitation and emerging trends could be influenced by the continent where it is implemented and hence should be analysed for any similarities and differences across the continents.

Finally, the knowledge, roles and responsibilities of Six Sigma experts differs according to Six Sigma hierarchical belt system (Pyzdek and Keller, 2014) and in terms of number of years of Six Sigma experience (Antony et al., 2019). Therefore, the limitations and emerging trends could be influenced by the years of experience of Six Sigma experts/consultants and also the Six Sigma belts and hence should also be analysed for any similarities and differences experienced across these clusters.

Research Methodology

The research questions driving this study are:

a) What are the top five limitations and emerging trends of Six Sigma from the viewpoint of Six Sigma experts from different continents, belt wise, years of experience and sectors?

b) Is there any difference in Six Sigma experts' (continent wise, belt wise, number of years' experience) perceptions on Six Sigma limitations and emerging trends?

c) Is there any difference in Six Sigma experts' perceptions on the limitations and emerging trends of Six Sigma between manufacturing, service and public sector?

To address the above research questions, the authors utilised an online survey for data collection targeted at large manufacturing, service and public sectors. This survey method is one of the most appropriate methods for this type of study, as it enables the collection of a large amount of information from respondents in a short period of time. The survey instrument developed for this study was divided into two sections, one to ascertain general information about the respondents and the second section was dedicated to listing fifteen limitations and emerging trends which were identified through a systematic literature review[2].

In the second part of the survey, seven-point Likert-type scales were used to measure the responses to the questions regarding limitations/ emerging trends. These scales provide

adequate levels of discrimination among the choices presented to respondents. Potential respondent's answers were measured with a seven-point scale, anchored at, for instance, 7 "strongly agree" and 1 "strongly disagree". The scale was used in order to assist respondents to make an exclusive and decisive choice [66]. Each of the limitation / emerging trend was measured using a single item scale mainly since each of the limitation / emerging trends were unambiguous and concrete. Studies have shown that the single item scale performed as well as a multi-item scale when the construct was unambiguous and concrete [67], [68]. Additionally, as Six Sigma experts are busy professionals and unnecessary long questionnaire may not be attractive to them, the short nature of the questionnaire scaffolds respondents in answering the survey in a short period of time. A pilot study was conducted during the scale development process. The online survey protocol was first piloted with 10 experts. Five were academics who have extensively published at least five Six Sigma articles and five were Six Sigma practitioners with high level belts (MBBs and BBs) and who have pursued a number of process improvement projects in their respective businesses [69]. The purpose of piloting the survey questionnaire was to validate it and ensure that the questions aligned with the research questions set by the researchers[70]. The comments and feedback from the pilot study were subsequently used to review the survey questions and make the questions more readable and relevant to the research. Most of the comments were positive and hence the survey questionnaire was deemed suitable for research. The revised online survey link was sent out to 1250 subject matter experts who are working in their respective organisations in roles such as MBBs, BBs or GBs or yellow belts. The contacts were obtained through LinkedIn and each of the respondents were contacted through email. The authors used three criteria in the selection of such subject matter expert; i) all respondents should have a minimum of three years' experience in their role as a process improvement specialist, ii) all respondents should have carried out a minimum of two process improvement projects and iii)

have been involved in at least three process improvement projects as a team member. Setting such criteria will enable the authors to glean knowledge from a high calibre of experts from the survey participants, who are responsible for the execution of process improvement related projects in their respective organisations.

A total of 307 responses were collated over a 24-week period, yielding a response rate of 24.56%. Easterby-Smith et al., [71] argue that a 20% survey response rate is widely considered to be sufficient. The sample characteristics are given in Table 2.

Table 2: Sample Characteristics

Type of characteristics	Classification	Manufacturing	Public Sector	Service	Total
Gender	Female	20	5	31	56
	Male	128	16	107	251
	Total	148	21	138	307
Six Sigma Belt	Black Belt	47	8	46	101
	Green Belt	45	7	23	75
	Master Black Belt	56	6	69	131
	Total	148	21	138	307
Continent	Africa	14	0	14	28
	Asia	13	5	21	39
	Europe	93	15	66	174
	North America	21	0	26	47
	South America	7	1	11	19
	Total	148	21	138	307

Experience	Less than five years	41	6	34	81
in Six Sigma	More than five years	107	15	104	226
	Total	148	21	138	307

All the questionnaires were sent out to survey participants on the same day. In order to test for non- response bias, we conducted a time trend extrapolation test[72], [73] by comparing early and late respondents in different continent samples. Early respondents were respondents who responded within first four weeks and late respondents were those in last four weeks during the twenty-four-week period. Moreover, the authors have also utilised peer reviewed articles for designing the questionnaire and send automatic reminders to some respondents in reducing non-response bias. Moreover, the authors have reassured all the participants well in advance that the data collected will be kept completely confidential. No significant differences were observed between early and late responses.

3. Research Findings and Discussions

The findings of the research study were analysed as (1) limitations and emerging trends of Six Sigma continent wise analysis, (2) limitations and emerging trends of Six Sigma sector wise analysis, (3) Limitations and emerging trends of Six Sigma Belt wise analysis and (4) Limitations and emerging trends of Six Sigma experience wise analysis

4.1 Limitations and emerging trends of Six Sigma continent wise

Experts from Africa, Asia, Europe, North and South America continents participated in this study. The continent wise top five limitations of Six Sigma are listed in tables 3, 4, 5, 6 and 7. For each question the scores were summed for all responses. High sum indicates that most respondents have agreed to the particular limitation or emerging trend. The mean scores was used to rank the limitations[74].

Table 3: Top five Six Sigma limitations and emerging trends identified by Asian experts

Limitations / Emerging trends	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	230	5.9
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	221	5.67
Variance reduction should not be the only goal of Six Sigma implementation	216	5.54
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	215	5.51
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	213	5.45

Four out of five emerging trends of Six Sigma also featured in the top five limitations and emerging trends in Asia. In Asia, it is perceived by experts that the limitation associated with variation reduction should not be the sole goal of Six Sigma featured in top five limitations. The perception of experts in relation to emerging trends suggests that Six Sigma experts in Asia are concerned with the integration of Six Sigma with Big data, Industry 4.0, Green agenda and SME and micro enterprises rather than being concerned about other limitations.

Table 4: Top five Six Sigma limitations and emerging trends identified by European experts

Limitations / Emerging trends	**Sum**	**Mean Scores**
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	975	5.6

Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	962	5.53
Variance reduction should not be the only goal of Six Sigma implementation	960	5.52
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	956	5.49
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	874	5.02

In Europe, experts' perceptions were focused on the emerging trends. However, all experts apart from experts in Asia recognised that Six Sigma's implementation limitation may have a negative impact on employee satisfaction. Experts in Asia did not consider employee satisfaction to be an important criteria and this may have been influenced by a large population and high unemployment rate [75], [76].

Table 5: Top five Six Sigma limitations and emerging trends identified by North American experts

Limitations / Emerging trends	**Sum**	**Mean Scores**
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	276	5.87
Variance reduction should not be the only goal of Six Sigma implementation	274	5.83
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	271	5.77
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	269	5.72
Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	238	5.06

The emerging trend of Integration of Six Sigma and Industry 4.0 did not feature in either Europe or North America. This may be explained partly because Industry 4.0 is so well

researched and implemented in Europe and North America [77]–[79] compared to other continents. Therefore, Six Sigma experts may not have considered it as a top-five emerging trend but rather as an implementation guideline. In other continents, Industry 4.0 is seen as an emerging trend because Industry 4.0 implementation is not as widespread and therefore it is seen as an emerging trend.

Table 6: Top five Six Sigma limitations and emerging trends identified by South American experts

Limitations / Emerging trends	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	119	6.26
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	114	6.0
Variance reduction should not be the only goal of Six Sigma implementation	113	5.95
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	106	5.58
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	104	5.47

Table 7: Top five Six Sigma limitations and emerging trends identified by African experts

Limitations / Emerging trends	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	163	5.82
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	160	5.71
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	157	5.61
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	156	5.57

Variance reduction should not be the only goal of Six Sigma implementation	150	5.36

In the continents of South America, Africa and Asia, the emerging trend of integration of Six Sigma with Big Data which is perceived to bring superior results to many organizations in the future was rated in the top rank by the Six Sigma experts. Big data poses many challenges and pitfalls in developing countries compared to developed countries [80]. Interestingly, Six Sigma experts perceived it as a challenge in developing continents as compared to developed continents such as North America and Europe.

An important question which is also worth investigating is whether any significant differences arose in the perceptions of Six Sigma experts across the continents studied. For this analysis, the data was tested for normality. Anderson Darling test was conducted and found that for all the variables do not follow normal distribution. As the data was non-normal, Kruskal-Wallis test [81] was conducted to test whether there is significant difference in mean scores of responses in limitation/ emerging trends across all continents. The Kruskal-Wallis test, a median test, can be considered as a backup method for ANOVA where the independent variable is categorical (three or more than three groups) but the dependent variable is not normally distributed. The null hypothesis is that these three-sample means are from the sample population, $\mu1=\mu2=\mu3$ [82]–[84]. The Kruskal-Wallis test significance value $p > 0.05$ showed that limitations/ emerging trends mean scores are not significantly different[82], [85], [86]. The significant differences in mean scores of limitations and emerging trends were identified among the continents. Table 8 summarises the tests and outcomes.

There was a significant difference in mean scores of responses across continents (Kruskal-Wallis ANOVA, $H=12.546$, $df=4$, $P<0.014$) for the emerging trend that Green and Six Sigma

are complementary to each other and where their integration would be beneficial. The mean values for North, South America and Europe are lower than when compared to those for Africa and Asia. Green Six Sigma is a relatively new concept compared to Six Sigma [22]. In both Asia and Africa, the Green Six Sigma concept is gaining in popularity, compared to other continents. Six Sigma experts perceived immense benefits to organizations when Green Six Sigma is applied to Africa and Asia, compared to countries which have already established the Green initiatives.

The mean scores emerging trend of integration of Six Sigma and Industry 4.0 was found to be significantly different across the continents (Kruskal-Wallis ANOVA, $H=17.032$, $df=4$, $P<0.002$). The mean scores in Europe and North America are lower compared to other continents as Industry 4.0 is implemented in Europe and North America to a large extent compared to other continents. The mean scores of emerging trend of the integration of Six Sigma with Big Data (with the potential to provide superior results in many organizations in the future) is significantly different across the continents (Kruskal-Wallis ANOVA, $H=10.637$, $df=4$, $P<0.031$). Six Sigma experts from Europe have lower mean values compared to other continents. The mean scores of emerging trend that Six Sigma is not suitable for public sector organizations is significantly different across the continents (Kruskal-Wallis ANOVA, $H=20.1$, $df=4$, $P<0.000$). The Six Sigma experts from Africa mean values were higher compared to those from other continents. In Africa, public sector underperformance is due to various factors beyond the control of organization such as political interference and terrorism etc. [87], [88]. Therefore, in the African context, Six Sigma may not be effective in solving external problems as these may be beyond the control of the organization, leading to Six Sigma experts perceiving it to be less effective in the public sector. The limitation of the failure rate of Six Sigma initiatives, similar to other organizational change initiatives, is very high, but the mean scores are found to be

significantly different across the continents (Kruskal-Wallis ANOVA, H=14.060, df=4, P<0.007). The perspectives of organizational change in Asia is different compared to other continents due to its socio-cultural dynamics [89]. The successful implementation of Six Sigma requires a successful organizational change management program [90] which takes care of contextually relevant socio-cultural factors. In the Asian context, the non-handling of these dynamics transmutes to a high failure rate, thus, the Six Sigma experts in Asia felt that the Six Sigma initiatives similar to other organizational change initiatives is very high.

Table 8: Continent Wise Kruskal-Wallis test on limitations and emerging trends of Six Sigma

	Africa (N=28)		Asia (N=39)		Europe (N=174)		North America (N=47)		South America (N=19)		Kruskall Wallis test
Limitations	**Sum**	**Mean**	**Sum**	**Mean**	**Sum**	**Mean**	**Sum**	**Mean**	**Sum**	**Mean**	**Sig**
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	156	5.57	215	5.51	874	5.02	227	4.84	93	4.89	0.014
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	136	4.86	213	5.45	857	4.93	221	4.70	106	5.58	0.002
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	163	5.82	230	5.90	962	5.53	269	5.72	119	6.26	0.031
Non-Standardization of Curriculum	126	4.50	169	4.33	722	4.15	197	4.20	88	4.63	0.291
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	157	5.61	200	5.13	956	5.49	271	5.77	104	5.47	0.225
Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation	96	3.43	120	3.08	553	3.18	133	2.84	74	3.89	0.321
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	160	5.71	221	5.67	975	5.60	276	5.87	114	6.00	0.429
Six Sigma is not suitable for public sector organizations	83	2.96	100	2.56	352	2.02	73	1.55	32	1.68	0.000
Six Sigma is TQM on steroids	116	4.14	154	3.95	608	3.50	162	3.45	60	3.16	0.104
Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	144	5.14	196	5.03	851	4.89	238	5.06	103	5.42	0.618
The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts	79	2.82	111	2.85	440	2.53	111	2.36	52	2.74	0.328
The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high	131	4.68	196	5.03	746	4.29	194	4.13	67	3.53	0.007
The initial cost of implementing Six Sigma in an organization is very high	128	4.57	172	4.41	691	3.97	195	4.15	64	3.37	0.095
The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instill confidence in Organizations to implement Six Sigma	119	4.25	168	4.31	692	3.98	171	3.64	81	4.26	0.315
Variance reduction should not be the only goal of Six Sigma implementation	150	5.36	216	5.54	960	5.52	274	5.83	113	5.95	0.344

4.2 Limitations and emerging trends of Six Sigma sector wise analysis

The limitations and emerging trends are also analysed on a sector wise basis. The Six Sigma experts from manufacturing, service and public sectors participated in this study. Tables 9, 10 and 11 depict the top five limitations of Six Sigma as perceived by the Six Sigma experts.

Table 9: Top five manufacturing sector limitations and emerging trends of Six Sigma

Limitations	**Sum**	**Mean Scores**
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	847	5.72
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	827	5.59
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	824	5.57
Variance reduction should not be the only goal of Six Sigma implementation	816	5.51
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	770	5.21

In the manufacturing sector, the emerging trends of Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implementation was prioritised, resourced and carefully managed. However, SME and micro enterprises find it very challenging to implement Six Sigma. As SMEs are not aware of Six Sigma or its limitations, many do not have the resources to implement six sigma project [91]. Interestingly, Six Sigma can be deployed in both large corporations and small companies [36]. However, the use of Six Sigma in SMEs is not very common due to various misconceptions about the topic, and a lack of understanding and awareness of the benefits of Six Sigma in the SME context [24]. Thus, there is a need for an implementation guideline for Six Sigma in SMEs for use in the manufacturing sector in order to mitigate challenges.

Table 10: Top five service sector limitations and emerging trends of Six Sigma

Limitations	Sum	Mean Scores
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	801	5.8
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	781	5.66
Variance reduction should not be the only goal of Six Sigma implementation	777	5.63
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	753	5.46
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	703	5.1

In a modern factory, machines are connected as a collaborative community requiring the utilization of advance-prediction tools, in order for big data to be systematically processed into information to explain uncertainties, and thereby make more "informed" decisions to create service innovations[92].

Table 11: Top five public sector limitations and emerging trends of Six Sigma

Limitations	Sum	Mean Scores
Variance reduction should not be the only goal of Six Sigma implementation	120	5.71
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	118	5.62
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	115	5.48
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	111	5.29
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	107	5.1

Therefore, the Six Sigma experts in the service sector perceived the top emerging trend to be the integration of Six Sigma with Big Data which can bring superior results to many organizations in the future. The variability within the service sector is encountered in many components, interfaces, and entities interacting within its systems. Variability could be due to different usage situations and conditions, operator-introduced variations in operating the system, and customer- introduced variability in service operations[93]. The objective of public service is to serve people from different strata of the society thus leading to different requirements needs. Consequently, variance reduction is not the only goal in the public sector. Important goals such as the satisfaction of all members of society are to the forefront of public service and as a result, Six Sigma experts perceived this to be the number one limitation in the public sector.

An important subject which is worth investigating is the question whether there was any significant difference in mean scores of Six Sigma experts across the sectors studied. As the data was non-normal the Kruskal-Wallis test [81], [82] was conducted.

Table 12: Sector-wise Kruskall-Wallis test for limitations and emerging trends

	Manufacturing (N=148)		Services (N=138)		Public Sector (N=21)		Kruskall Wallis test
Limitations	**Sum**	**Mean**	**Sum**	**Mean**	**Sum**	**Mean**	**Sig**
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	758	5.12	703	5.10	104	4.95	0.751
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	770	5.21	656	4.75	107	5.10	0.006
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	827	5.59	801	5.80	115	5.48	0.352
Non-Standardization of Curriculum	586	3.96	627	4.55	89	4.23	0.001
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	824	5.57	753	5.46	111	5.29	0.471
Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation	510	3.45	400	2.90	66	3.14	0.053
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	847	5.72	781	5.66	118	5.62	0.688
Six Sigma is not suitable for public sector organizations	327	2.21	261	1.89	52	2.48	0.125
Six Sigma is TQM on steroids	513	3.47	504	3.65	83	3.95	0.394
Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	751	5.07	679	4.92	102	4.86	0.562
The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts	351	2.37	375	2.72	67	3.19	0.012
The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high	622	4.20	617	4.47	95	4.52	0.305
The initial cost of implementing Six Sigma in an organization is very high	612	4.14	543	3.93	95	4.52	0.212
The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instill confidence in Organizations to implement Six Sigma	610	4.12	540	3.91	81	3.86	0.513
Variance reduction should not be the only goal of Six Sigma implementation	816	5.51	777	5.63	120	5.71	0.800

The mean scores of emerging trend of the integration of Six Sigma and Industry 4.0 is not fully explored yet and the perception differed significantly across the sectors (Kruskal-Wallis ANOVA, H=10.241, df=2, P<0.006) suggesting that it would be one of the next big emerging topics. The manufacturing sector mean score was higher, suggesting that the concerns amongst experts in the manufacturing sector include a need for an integration methodology to guide the manufacturing sector through the integration. As Industry 4.0 has first been applied in the manufacturing sector rather that the service sector, Six Sigma experts perceived its

importance for manufacturing compared to services. The mean scores of limitation non-Standardization of the training / education curriculum was perceived to be significantly different across the sectors (Kruskal-Wallis ANOVA, H=13.069, df=2, P<0.001). The service sector mean values were higher than others suggesting there is an urgent need to standardise Six Sigma curriculum for use in the service sector. Six Sigma roll out in the service sector is a challenge [1], therefore, there is a need for the standardisation of the curriculum in order for its effective implementation. The mean scores of limitation benefits accruing from Six Sigma implementation are minimal when compared with the effort invested was perceived differently across the sectors (Kruskal-Wallis ANOVA, H=8.768, df=2, P<0.012) . The public sector mean values were higher, given that Six Sigma is an emerging area in the public sector. Tangible benefits in the public sector could include a reduction in; time, space and cost, with improved quality and dependability impact and also efficiency and effectiveness. Intangible benefits in the public sector might include; a better understanding of customers and cross-team synergies, a rise in employee motivation and morale. Six Sigma benefits in terms of tangible and intangible benefits in the public sector are often difficult to quantify. This could be due to the inherent nature of public service, as it is built on the fundamental principles such as democratic citizenship, community and civil society, and organizational humanism and discourse theory [94].

4.3 Limitations / emerging trends of Six Sigma Belt Wise Analysis

The limitations are also examined belt wise. Tables 13, 14 and 15 depict the top five limitations as perceived by Master Black Belt, Black Belt and Green Belt experts.

Table 13: Top Five limitations and emerging trends of Master Black belt experts

Limitations	**Sum**	**Mean Scores**
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	766	5.85
Variance reduction should not be the only goal of Six Sigma implementation	754	5.76
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	750	5.73
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	731	5.58
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	653	4.99

The master black belt standard provides technical leadership support for the Six Sigma program [95]. In a strategic and leadership sense, master black belts have perceived that Six Sigma programs in SMEs and Micro-enterprises are very challenging but also highlight that they could be very rewarding if implemented properly as the top limitation/ emerging trends.

Table 14: Top Five limitations and emerging trends of Black belt experts

Limitations	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	574	5.68
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	572	5.67
Variance reduction should not be the only goal of Six Sigma implementation	558	5.53
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	549	5.44
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	527	5.21

Black Belt status are technically oriented individuals held in high regard by their peers [95]. In this survey, they have identified the significance of Six Sigma alignment with big data. Therefore, they have perceived that the integration of Six Sigma with Big Data can generate superior results for many organizations in the future as the top limitation / emerging trends.

Table 15: Top Five limitations and emerging trends of Green belt experts

Limitations	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	319	5.6
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	311	5.46
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	307	5.39
Variance reduction should not be the only goal of Six Sigma implementation	301	5.28
Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	300	5.26

Green Belts are Six Sigma project leaders who are capable of forming and facilitating Six Sigma teams and managing Six Sigma projects from concept to completion [95]. Green Belt experts also identified Six Sigma integration with Big data as an emerging trend, but they also perceived Six Sigma to have a negative impact on employees if it is not implemented properly. An important subject which is worth investigating is, whether there was any significant difference in the perception of Six Sigma experts who are master black belt, black belt and Green Belt. Table 16 depicts the results of the belt wise Kruskal-Wallis test and analysis

Table 16: Belt-wise Kruskal-Wallis test on limitations and emerging trends of Six Sigma

	Black Belt (N=101)		Green (N=75)		Master Black Belt (N=131)		Kruskall Wallis test
Limitations	**Sum**	**Mean**	**Sum**	**Mean**	**Sum**	**Mean**	**Sig**
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	527	5.21	477	5.14	653	4.99	0.479
Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	509	5.04	473	5.00	645	4.92	0.536
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	574	5.68	519	5.60	750	5.73	0.530
Non-Standardization of Curriculum	418	4.13	398	4.14	568	4.34	0.260
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	549	5.44	505	5.46	731	5.58	0.674
Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation	316	3.13	361	3.63	376	2.87	0.001
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	572	5.67	509	5.39	766	5.85	0.099
Six Sigma is not suitable for public sector organizations	219	2.17	244	2.63	224	1.71	0.000
Six Sigma is TQM on steroids	359	3.55	380	4.21	431	3.29	0.008
Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	507	5.02	486	5.26	632	4.82	0.226
The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts	251	2.49	283	3.00	315	2.40	0.005
The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high	416	4.12	430	4.70	569	4.34	0.201
The initial cost of implementing Six Sigma in an organization is very high	405	4.01	406	4.49	514	3.92	0.196
The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instill confidence in Organizations to implement Six Sigma	409	4.05	417	4.65	481	3.67	0.003
Variance reduction should not be the only goal of Six Sigma implementation	558	5.53	501	5.28	754	5.76	0.127

The results suggest that six sigma as a structured and disciplined approach to problem-solving may stifle the employee creativity and innovation was perceived significantly different by Master Black Belts, Black Belts and Green Belts (Kruskal-Wallis ANOVA, $H=14.741$, $df=2$, $P<0.001$) . The mean score of Green Belts was higher than Master Black Belt and Black Belt. The differences may be explained in terms of the ranking order of Belt

experts as Green Belts usually assist Black belts with their projects. In general, black belts guide Green Belts to define their project priorities [95]. Given the formalised relationship, green belts may have perceived that such a structured and disciplined approach stifles the employee creativity and innovation. The emerging trend of six sigma as not being suitable for public sector organizations was also perceived differently by different belt experts (Kruskal-Wallis ANOVA, $H=19.803$, $df=2$, $P<0.000$). The Master Black Belts mean score was the lowest suggesting that those experts who are responsible for the strategic implementation of Six Sigma perceive that Six Sigma is suitable for public organizations. The limitation of Six Sigma is TQM on steroids is perceived differently by Six Sigma experts (Kruskal-Wallis ANOVA, $H=11.268$, $df=2$, $P<0.008$). The Mean Score of Green Belts was higher than those of Master Black Belts and Black Belts. As the Green Belt training is shorter (in terms of projects content and experience) in comparison with other Belt training, it is likely that Green Belts may not appreciate the uniqueness of Six Sigma compared to TQM or other quality management programs. The distribution of technical limitations of Six Sigma (for example 1.5σ shift) need to be addressed to instil confidence in organizations to implement Six Sigma is perceived differently by the Six Sigma experts with different belt levels (Kruskal-Wallis ANOVA, $H=13.397$, $df=2$, $P<0.003$). The 1.5σ shift was one of the most controversial topics among the Six Sigma experts [96]. The Master Black Belts and Black Belts mean scores were lower compared to Green Belts. This suggests that as the experts spend more time on theoretical and practical aspects of Six Sigma, they have more clarity regarding technical limitations. The limitations that benefits due to Six Sigma implementation for companies are minimal with respect to the efforts is perceived differently by the Six Sigma experts with different belt levels (Kruskal-Wallis ANOVA, $H=12.725$, $df=2$, $P<0.005$). The mean scores of Green Belts are higher compared to Master Black Belts and Black Belts suggesting that as

one gains knowledge and experience in Six Sigma, they appreciation of Six Sigma benefits with respect to efforts improve.

4.4 Limitations / emerging trends of Six Sigma Experience Wise Analysis

This study conducted an analysis of Six Sigma experts' perceptions based on their number of years' experience. For the purpose of the analysis, the experience categories were classified as Six Sigma experts with less than five years of experience and those with more than five years of experience. The analysis was conducted on both categories. Tables 17 and 18 summarise the top five limitations associated with expert's experience in each category.

Table 17: Top five limitations and emerging trends of experts with experience of less than five years of experience

Limitations	**Sum**	**Mean Scores**
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	464	5.73
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	440	5.43
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	439	5.42
Variance reduction should not be the only goal of Six Sigma implementation	432	5.34
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	419	5.17

The experts with less than five years of experience were more concerned with emerging trends such as Big data. Whereas, experts with more than five years of experience suggest that the importance of Six Sigma in SMEs and Micro-enterprises are very challenging but could be very rewarding if implemented properly.

Table 18: Top five limitations and emerging trends of experts with experience of more than five years of experience

Limitations	Sum	Mean Scores
Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	1307	5.78
Variance reduction should not be the only goal of Six Sigma implementation	1281	5.67
Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	1279	5.66
Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	1248	5.52
Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	1146	5.07

An important matter, which is worth investigating, is whether there was any significant difference in the perception of Six Sigma experts who are more experienced on the Six Sigma limitations / emerging trends. Table 19 depicts the experience wise analysis.

The limitation six sigma as a structured and disciplined approach to problem-solving that may stifle the employee creativity and innovation was perceived significantly different (Mann Whitney U Test statistic =7385.0 $P<0.008$). The less experienced experts (with less than five years of experience) felt that the structured and disciplined approach will stifle creativity compared to the more experienced experts (with more than five years of experience). This suggests that experienced Six Sigma experts do not perceive Six Sigma to stifle employee creativity and innovation.

The emerging trend that Six Sigma initiatives in SMEs and Micro-enterprises are very challenging, but such initiatives could be very rewarding if they were implemented properly was perceived significantly different (Mann Whitney U Test statistic =10476.00, $P<0.037$) . The more experienced experts mean score is higher than that of the less experienced Six

Sigma experts, indicating that experienced experts have experienced the challenges associated with the application of Six Sigma in SMEs and Micro-enterprises.

The technical limitations of Six Sigma such as the 1.5σ shift need to be addressed in order to instil confidence in organizations in their implementation of six sigma (Mann Whitney U Test statistic =7478.0 $P<0.013$). As the more experienced experts mean score was lower it suggests that as the experts gain more experience such technical limitations become more understood and less of an issue for the experts.

The limitation variance reduction should not be the only goal of six sigma implementation is perceived differently by the experts (Mann Whitney U Test statistic =10534.5 $P<0.03$). The experienced experts (with more than five years of experience) mean scores were significantly higher than those with less than five years of experience suggesting variance reduction should not be the only goal in Six Sigma projects. Such an approach is very important in-service sectors, as variability is not always viewed as negative in the service sector.

Table 19: Experience-wise Mann Whitney test limitations and emerging trends of Six Sigma

		Less than five years (N=81)		More than five years (N=226)		Mann Whitney test
	Limitations	**Sum**	**Mean**	**Sum**	**Mean**	**Sig**
1	Green and Six Sigma are complementary to each other and their integration would be beneficial to many companies	419	5.17	1146	5.07	0.349
2	Integration of Six Sigma and Industry 4.0 is not fully explored yet and it will be one of the next big emerging topics	416	5.14	1117	4.94	0.313
3	Integration of Six Sigma with Big Data can bring superior results to many organizations in the future	464	5.73	1279	5.66	0.742
4	Non-Standardization of Curriculum	336	4.14	967	4.28	0.373
5	Poor implementation of Six Sigma can have a negative impact on employee satisfaction.	440	5.43	1248	5.52	0.728
6	Six Sigma as a structured and disciplined approach to problem solving may stifle the employee creativity and innovation	288	3.56	688	3.05	0.008
7	Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises are very challenging but could be very rewarding if implemented properly	439	5.42	1307	5.78	0.037
8	Six Sigma is not suitable for public sector organizations	183	2.26	457	2.02	0.467
9	Six Sigma is TQM on steroids	314	3.88	786	3.48	0.078
10	Six Sigma, if not implemented properly, may have a negative impact on customer satisfaction	412	5.09	1120	4.96	0.688
11	The benefits due to Six Sigma implementation for companies are minimal with respect to the efforts	219	2.70	574	2.54	0.233
12	The failure rate of Six Sigma initiatives like any other organizational change initiatives is very high	355	4.38	979	4.33	0.856
13	The initial cost of implementing Six Sigma in an organization is very high	345	4.26	905	4.00	0.218
14	The technical limitations of Six Sigma like 1.5σ shift needs to be addressed to instill confidence in Organizations to implement Six Sigma	357	4.41	874	3.87	0.013
15	Variance reduction should not be the only goal of Six Sigma implementation	432	5.34	1281	5.67	0.030

4. Conclusion

The purpose of this study is to identify the limitations/emerging trends of Six Sigma from the viewpoint of Six Sigma experts from different continents, belt wise, years of experience in Six Sigma and in different sectors. Through an online survey, the Six Sigma experts identified the limitations / emerging trends of Six Sigma. The analysis focused on identifying the top five limitations / emerging trends from Six Sigma experts by continent, sector, Six Sigma Belt and experience of Six Sigma experts.

The *integration of Six Sigma with Big Data* was found among to be the topmost emerging trend with Asian, South America, and Africa experts. Experts in Europe and North American, in addition to experts from manufacturing sector agreed that *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises would be very challenging, however will be very rewarding if implemented properly.* In service sector the integration *of Six Sigma with Big Data is the topmost emerging trend, and* public sector experts felt *variance reduction should not be the only goal of Six Sigma implementation*.

The master black belts and those experts has more than five years of experience perceived *Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises is very challenging, but would be rewarding if implemented properly*, whereas Black and Green Belts perceived *Integration of Six Sigma with Big Data*. However, Six Sigma expert with less than five years of experience felt *integration of Six Sigma with Big Data*.

The first limitation of the study is the representation of all continents. As the response rate from some continents was very low, hence the continent of Australia was not included in the study. The second limitation involves the use of a single-item scale for each limitation / emerging trend. The third limitation of the study considers the general limitation of survey design, where memory decay could influence the study. To mitigate this limitation, perceptual experts' data from Six Sigma experts with Green, Black and Master Black belts was used.

This is the first global study to quantitatively analyse the limitations and emerging trends of Six Sigma from data obtained by Six Sigma experts. Future research should be directed on the emerging trends. The integration of Six Sigma and Industry 4.0 is not fully explored yet and future research should investigate the development of an integration framework. The integration of Six Sigma with Big Data can provide superior results to many organizations

and future research should be directed to the development of new tools for big data analysis. In addition, the existing tools can be further modified to incorporate big data. Green Six Sigma research is in the preliminary stages and therefore a well-established generic framework for its implementation is also needed. Six Sigma in public sector organizations is an under researched subject and future research study should be directed in different public services where Six Sigma can be implemented. Six Sigma in Small and Medium Sized Enterprises and Micro-enterprises research should also be expanded for the purpose of developing an implementation framework, tools, curriculum development and trainings etc.

Theoretical and Practical Implications

Six Sigma as a business strategy is used by many organizations for process improvement since nearly last four decades and is reported to have saved millions of dollars for various organizations despite of their nature; service, manufacturing and public sector. Previous studies have also reported limitations of Six Sigma along with modern trends considering the changing face of modern organizations due to fourth industrial revolution. This study evaluates the limitations and emerging trends of Six Sigma from the perspectives of Six Sigma experts through a global survey and thus being the first study to evaluate the limitations and emerging trends globally. Understanding the major limitations / emerging trends/ research gaps will create a foundation for both industrial experts and leading academic scholars for a greater understanding on the existing gaps so that further research can be executed to address them in the forthcoming years. Further, it can form the basis upon which to discuss and develop combined academic and industry strategies to address and overcome these limitations. Our study suggests that the importance of integration of Six Sigma with Big data and Industry 4.0 has been a major emerging trend which researchers and practitioners must exploit. Researchers can use the results of this study to develop an implementation framework which integrates big data and Six Sigma which will benefit the

practitioners. Industry 4.0 further stresses the importance of vertical, horizontal and end to end integration in a goal directed manner to achieve business excellence. The authors believe that practitioners can use this study to integrate Six Sigma methodology with Big Data throughout the three phases of integration. The study also suggests the need for Six Sigma practitioners to customise the Six Sigma methodology further to implement the same in small, medium and micro enterprises as there is yet no practical and proven frameworks exist in authors' opinion. Green Six Sigma is another aspect which senior managers should consider while applying the green principles and concepts in their organizations. Managers can further consider having tangible green objectives in terms of decreasing emissions, energy consumption, waste and environmental costs, at the same time increasing environmental revenues while designing Six Sigma process improvement strategies. Although this is not seen as a short-term strategy to be adopted for many organisations, the authors argue that the integration of Green with Six Sigma will be of great demand in the forthcoming years especially when the agenda for environmentally products become a priority for organisations.

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Acknowledgement

We thank all the participants in the online survey for responding despite their busy schedule and further we also thank the reviewers for constructive feedback which have improved the quality of the paper.

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